The Effect of Cement and Water Cement Ratio on Concrete Paving Block

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Abstract

This paper presents experimental results regarding the effects of cement content and water cement ratio (w/c) in the production of concrete paving block. Laboratory trials were conducted to compare and investigate the effect of 12 % and 15 % cement content in concrete mixtures at five different w/c ratios. In total, 60 concrete mixtures were cast and tested to determine dry density, compressive strength and skid resistance of concrete paving block samples. The design strength level ranging from 20 to 33 MPa and 31 to 42 MPa was achieved using w/c ratio from 0.50 to 0.70 for 12 % cement content and 0.45 to 0.65 for 15 % cement content, respectively. This study shows that, it was feasible to produce paving blocks prepared with 12 % cement that satisfied the minimum compressive strength (30MPa) in accordance to MA20 for trafficked area less than 3 tonnes gross weight.

Keywords: Concrete Paving Block; Cement, Water Cement Ratio, Skid Resistance

1. Introduction

In various countries, the concrete block pavement (CBP) becomes an attractive engineering and economical alternative to the both flexible and rigid pavement [1]. The strength, durability and aesthetically pleasing surface of paver [2] have made CBP ideal for many commercial, municipal and industrial applications, such as parking area, pedestrian, traffic intersection, container yards, etc.

In conventional, concrete paving block are produce based on a mixture of Portland cement, natural fine and coarse aggregate. The cement in the concrete mix is the finest material, and therefore has the greatest surface area per unit mass, and thus the greatest water requirement per unit mass. The high water requirement of the cement is also moderated by much lower water requirement of the aggregate, as typically most paving mixes have aggregate: cement ratio raging between 5 and 7 [3].

For any given cement content there is optimal water content ratio. Using more water in the mix assist in reducing macroscopic entrapped voids, but too much water increases microscopic capillary voids. Conversely using less water has the potential to allow a closer packing of cement particles, but makes it so much more difficult to expel the air voids, as clearly less water means reduces lubrication/mobility.

Thus, the purpose of laboratory mix design in this study is to optimize the water content for 12 % and 15 % cement content in each mixture. Optimizing the water content optimizes the overall strength of the concrete, and has potential to produce a hardened concrete paving block of the required minimum quality.

2. Experimental Work

2.1 Material Properties

The materials used to develop concrete mixture in this study consist of natural aggregate, additive and ordinary Portland cement complying with MS 522. The natural aggregates used include natural river sand as the fine aggregate having a maximum particle size of 4 mm and fineness modulus of 2.62 and crushed granite with nominal size less than 10 mm and 5.84 fineness modulus as the coarse aggregate. The weight ratio of course to fine aggregate of all paving blocks was kept to about 1: 2 throughout the whole experimental works.

2.2 Concrete Mixture

Two series of mixes were prepared using coarse and fine aggregate, cement, water and additive. The difference between the two series was the cement to aggregate and sand ratio. Where, (cement: aggregate: sand) 12 %: 29.33 %: 58.67 % and 15 %: 28.33 %: 56.67 % were used in series I and II, respectively.

A total of five w/c ratios designated ranging from 0.50 to 0.70 and 0.45 to 0.65 with cement contents of 242 kg/m^3 and 298 kg/m^3 were prepared in series I and II, respectively.

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The mixed materials used were approximately 8.5 kg for each batch of three paving blocks samples.

2.3 Fabrication and Curing of Test Pavers

The paving blocks were fabricated in steel moulds with internal dimensions of 200 mm in length, 100 mm in width and 60 mm in depth as shown in Figure 1. The mix was poured into the mould in two layers of about equal depth. Compaction was applied manually using a hammer at each layer. The concrete blocks were then removed from the steel moulds one day after casting and cured in air at room temperature (Figure2) for 7 and 28 days until tested.

Figure 1: Fabrication and demoulding of concrete paving block specimens

Figure 2: Air curing at room temperature

2.4 Test Methods

A range of tests were carried out at the Structure and Material Laboratory, in Universiti Teknologi Malaysia to determine dry density, skid resistance and compressive strength at 7 and 28 days of the paving blocks specimens. The skid resistance of paving block was determined using a British Pendulum Skid Resistance Tester (Figure 3) and it was expressed as the measured British Pendulum Number (BPN) as specified by ASTM E303-93 [4].

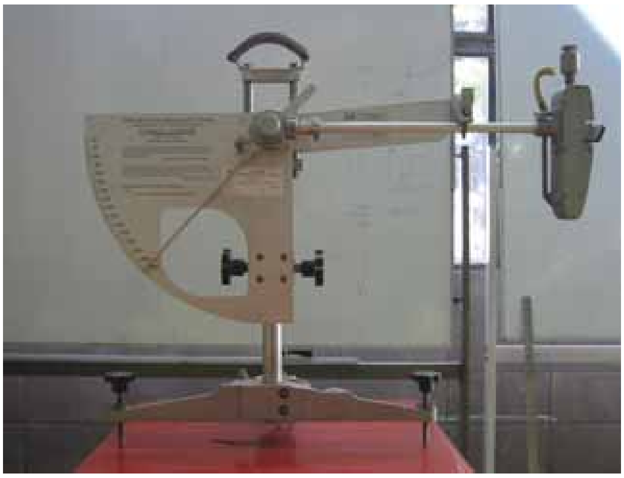

Figure 3: Skid resistance test

The compressive strength was determined using a compressive testing as shown in Figure 4. The load, increased at a rate of 0.30 kN/s, was applied to the nominal area of block specimen. Prior to the loading test, the block specimens were soft capped with two pieces of plywood. The compressive strength was calculated by dividing the failure load by the loading area of the block specimen.

Figure 4: Compressive strength test

3. Experimental Results and Discussions

3.1 Dry Density

Results in Figure 5 indicated that dry density decreased to as low as about 2.09 g/cm^3 at 0.50 w/c for 12 % cement content. For 15 % cement content the dry density of the concrete blocks ranged from 2.16 to 2.20 g/cm^3 depending on the w/c ratio in the mixture. Because of high specific gravity of cement, unit weight of mixtures containing 15 % cement is slightly higher compare with 12 % cement content at the same w/c ratio. Moreover, decrease of w/c ratio in concrete mixture, which in turn reduces the unit weight of the mixtures.

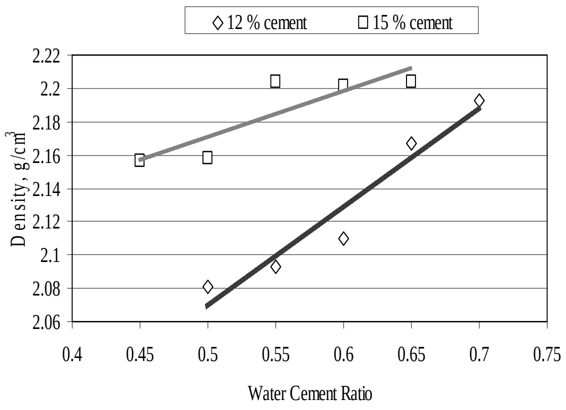

Figure 5: Dry density of paving blocks

3.2 Compressive Strength

The results of series I and II are summarized in Figure 6 and 7, respectively. Each presented value is an average of three samples measurement. The results presented in Figure 6 shows a systematic reduction in compressive strength with the decrease in w/c ratio for the paving blocks. The reason for the strength reduction could be attributed by insufficient water in the spaces between the cement grains to fully convert each individual grain of cement into gel. Therefore the inner cores of the cement particles remain unhydrated. But in series I specimens, it can be seen that the paving block specimens prepared at 0.65 and 0.70 w/c ratio satisfy the requirement of MA20 [5] with the average compressive strength higher than 30 MPa.

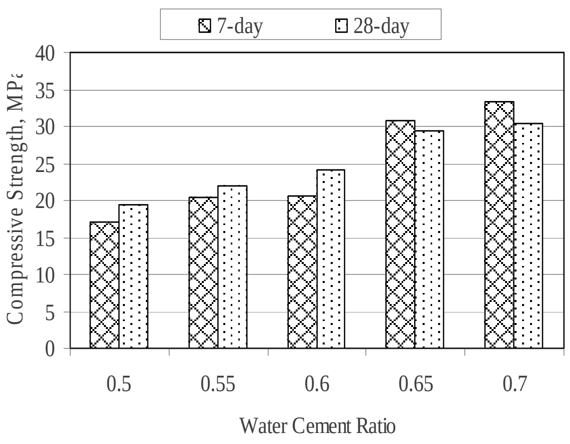

Figure 6: Compressive strength of series I paving blocks

The results presented in Figure 7 indicate that, the 7-day and 28-day compressive strength of series II paving blocks at five different w/c ratios. In the five w/c ratio, 0.55 w/c ratio gained the highest strength (42 MPa) compare to other w/c ratio. It is believed that at this w/c ratio, cement grains were close to each other to begin with the greatly increase in density of the microstructure and consequently compressive strength.

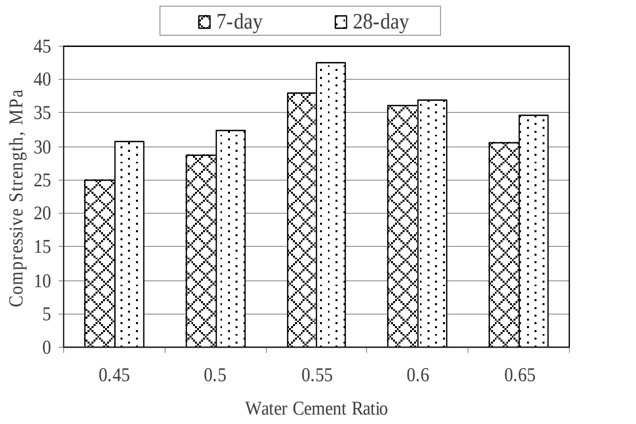

Figure 7: Compressive strength of series II paving blocks

3.3 Skid Resistance

Skid resistance was measured in accordance to ASTM E3030-93, four swings of the pendulum were made for each test surface paving block. The relationship between w/c ratio and BPN is shown in Figure 8. In general, the blocks produced in this study satisfy ASTM requirement that BPN were higher than 45. It is found that skid resistance was slightly higher for low w/c ratios. It was mainly due to the rough surface texture of paving blocks to create more friction as the pendulum passed across it.

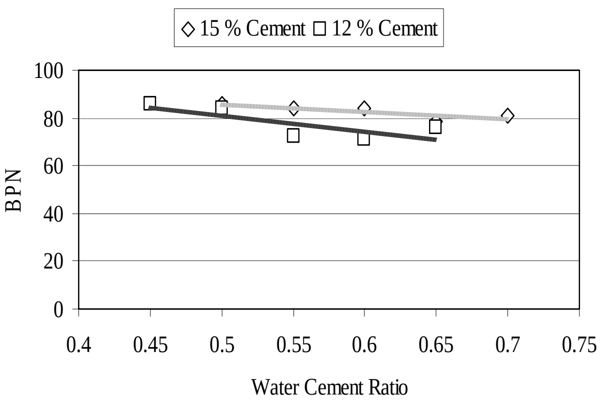

Figure 8: Skid resistance of paving block specimens

4. Conclusions

1. Dry density and compressive strength of concrete paving block is affected differently depending on cement content and w/c ratio. Clearly, if the cement content increases relative to the optimum of water in the concrete mixture, resulting in better dry density and compressive strength.
2. The test results indicated that there was an optimum w/c ratio (0.70 and 0.55) for every cement contents (12 % and 15 %), respectively.
3. It is possible to fabricate paving block containing 12 % cement at 0.70 w/c ratio that satisfied the minimum compressive strength (30MPa) in

accordance to MA20 for trafficked area less than 3 tonnes gross weight.

4. Concrete paving block at low w/c ratios is found to provide better skid resistance.

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